

WIDE AREA LOAD BALANCING OF WEB TRAFFIC

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FIELD OF THE INVENTION

The present invention relates to transmission of data in a network environment. More specifically, the present invention relates to methods and apparatus for improving the efficiency with which data are transmitted over the Internet. Still more specifically, the present invention relates to methods and apparatus for transparently redirecting network traffic to a selected replica of particular web content that is located closest to a client that is requesting such web content.

BACKGROUND OF THE INVENTION

Generally speaking, when a client platform communicates with some remote server, whether via the Internet or an intranet, it crafts a data packet which defines a TCP connection between the two hosts, i.e., the client platform and the destination server. More specifically, the data packet has headers which include the destination IP address, the destination port, the source IP address, the source port, and the protocol type. The destination IP address might be the address of a well known World Wide Web (WWW) search engine such as, for example, Yahoo, in which case, the protocol would be TCP and the destination port would be port 80, a well known port for http and the WWW. The source IP address would, of course, be the IP address for the client platform and the source port

would be one of the TCP ports selected by the client. These five pieces of information define the TCP connection.

Given the increase of traffic on the World Wide Web and the growing bandwidth demands of ever more sophisticated multimedia content, there has been constant pressure to find more efficient ways to service data requests than opening direct TCP connections between a requesting client and the primary repository for the desired data. Interestingly, one technique for increasing the efficiency with which data requests are serviced came about as the result of the development of network firewalls in response to security concerns. In the early development of such security measures, proxy servers were employed as firewalls to protect networks and their client machines from corruption by undesirable content and unauthorized access from the outside world. Proxy servers were originally based on Unix machines because that was the prevalent technology at the time. This model was generalized with the advent of SOCKS which was essentially a daemon on a Unix machine. Software on a client platform on the network protected by the firewall was specially configured to communicate with the resident demon which then made the connection to a destination platform at the client's request. The demon then passed information back and forth between the client and destination platforms acting as an intermediary or "proxy."

Not only did this model provide the desired protection for the client's network, it gave the entire network the IP address of the proxy server, therefore simplifying the problem of addressing of data packets to an increasing number of users. Moreover, because of the storage capability of the proxy server, information retrieved from remote servers could be stored rather than simply passed through to the requesting platform. This storage capability was quickly recognized as a means by which access to the World Wide Web could be accelerated. That is, by storing frequently requested data, subsequent requests for the same

data could be serviced without having to retrieve the requested data from its original remote source. Currently, most Internet service providers (ISPs) accelerate access to their web sites using proxy servers.

Unfortunately, interaction with such proxy servers is not transparent, requiring each end user to select the appropriate proxy configuration in his or her browser to allow the browser to communicate with the proxy server. For the large ISPs with millions of customers there is significant overhead associated with handling tech support calls from customers who have no idea what a proxy configuration is. Additional overhead is associated with the fact that different proxy configurations must be provided for different customer operating systems. The considerable economic expense represented by this overhead offsets the benefits derived from providing accelerated access to the World Wide Web. Another problem arises as the number of WWW users increases. That is, as the number of customers for each ISP increases, the number of proxy servers required to service the growing customer base also increases. This, in turn, presents the problem of allocating packet traffic among multiple proxy servers.

Another technique for increasing the efficiency with which data requests are serviced is described in commonly assigned, copending U.S. Patent Application No. 08/946,867 for METHOD AND APPARATUS FOR FACILITATING NETWORK DATA TRANSMISSIONS filed October 8, 1997, the entirety of which is incorporated herein by reference for all purposes. The invention described in that copending application represents an improvement over the proxy server model which is transparent to end users, high performance, and fault tolerant. By altering the operating system code of an existing router, the router is enabled to redirect data traffic of a particular protocol intended for a specified port, e.g., TCP with port 80, to one or more caching engines connected to the router via an

interface having sufficient bandwidth such as, for example, a 100baseT interface. If there are multiple caching engines connected to the cache-enabled router, the router selects from among the available caching engines for a particular request based on a simple algorithm according to which a particular group of addresses is associated with each caching engine.

5 The caching engine to which the request is re-routed "spoofs" the requested destination platform and accepts the request on its behalf via a standard TCP connection established by the cache-enable router. If the requested information is already stored in the caching engine, i.e., a cache "hit" occurs, it is transmitted to the requesting platform with a header indicating its source as the destination platform. If the requested information is not in
10 the caching engine, i.e., a cache "miss" occurs, the caching engine opens a direct TCP connection with the destination platform, downloads the information, stores it for future use, and transmits it to the requesting platform. All of this is transparent to the user at the requesting platform which operates exactly as if it were communicating with the destination platform. Thus, the need for configuring the requesting platform to suit a particular proxy
15 configuration is eliminated along with the associated overhead. Moreover, traffic may be easily allocated among as many caching engines as become necessary. Thus, content caching provides a way to compensate for the bandwidth limitations discussed above.

Another specific embodiment of a packet redirection protocol which may be used to implement such a network caching technique is described in copending, commonly assigned,
20 U.S. Provisional Patent Application No. 60/168,862 for METHOD AND APPARATUS FOR REDIRECTING NETWORK TRAFFIC filed December 2, 1999, the entirety of which is incorporated herein by reference for all purposes. According to a specific embodiment described in that application, the network caches have the capability of determining that particular redirected packets should be transmitted back to the redirecting router and

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reinserted into the original traffic flow. This may be done in a manner transparent to the source or destination of the packets. An example of a case in which packets would need to be reinserted in the original flow might be where the cache recognizes the source and destination pairs identified by the packets as corresponding to a connection requiring IP-based authentication. Another example would be where the cache is overloaded and is currently unable to handle all of the redirected traffic.

A technique conceptually related to content caching referred to as content co-location has also been developed to provide faster access to certain types of data. That is, a large amount of Internet content resides on machines in the U.S. Client machines in remote geographic locations such as New Zealand or Australia typically have two ways of retrieving such content, i.e., via terrestrial links (bidirectional and fast, but expensive) and satellite links (mostly unidirectional and relatively cheap, but slow).

Content co-location provides one way to facilitate faster access to such content for geographically remote users. According to this technique, servers are provided in the geographically remote areas which store at least some of the content of the original site, e.g., image files. Akamai and Sandpiper provide such "co-loc" facilities to content providers. When a client requests a page containing such objects, the html refers to the objects by object names which correspond to the co-loc provider. These object names are then resolved by the client's browser to an IP address corresponding to the closest co-loc facility.

While content co-location techniques have proven to be relatively effective, browsers must constantly perform the object name resolution when parsing ordinary html to access the correct co-location facility. Thus, the clients must configure their own browser to work with specific replicas for various content providers. That is, redirection of traffic from a client to a replica is not transparent. This configuration task may prove difficult or impossible, as

well as time-consuming to the client. Additionally, there are no efficient mechanisms for determining which replica is closest to a particular client. For example, when a content provider expands its number of replicas within the field, each client's browser would have to be updated to determine which replica is the closest.

- 5 Therefore, there is a need for mechanisms for efficiently and transparently routing requests from a client to a closest replica upon which the requested object is located.

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SUMMARY OF THE INVENTION

Accordingly, the present invention provides an apparatus and method for intelligently routing a request from a client to a selected device (e.g., replica or server). Mechanisms are also provided for intelligently and transparently passing traffic back and forth between the client and the selected device once a connection is established.

In one embodiment, a method of facilitating redirection of traffic between a server and a client to between the client and a nearest replica selected from a plurality of replicas is disclosed. A packet that is travelling between a client and a server or between the client and a replica is received (e.g., by the client's gateway router). When the received packet is a start packet that is travelling from the client to the server, the start packet is altered to indicate that the start packet should be forwarded to any replica that duplicates the data content of the server. When the received packet is an acknowledgement packet that is received first (e.g., from a replica or server), the acknowledgement is altered so that it spoofs the server when the acknowledgement originates from the replica. When the received packet is a subsequent packet received after the start packet and the acknowledgement packet, the subsequent packet is altered so that it spoofs the server when the subsequent packet originates from the replica. Otherwise, the subsequent packet is altered so that it goes to the replica when the subsequent packet originates from the client.

In one implementation, the server is spoofed by replacing a source identifier of the received packet with a destination identifier of the start packet. In another implementation, the server is spoofed by encapsulating the received packet with a source identifier that equals the destination identifier of the start packet. In yet another implementation, the received packet is encapsulated and the server is spoofed by cracking the received packet. In a specific embodiment, the start packet is altered by adding a tag to or modifying the tag of the

start packet to indicate that the start packet should be forwarded to any replica that duplicates data content of the server. In a preferred embodiment, a reset is sent to the replica or the server identified as a source of the received packet when the received packet is received after the first received acknowledgement packet.

5 In a second embodiment, a start packet sent from a client to a server is received (e.g., by a destination server or server gateway router). When the start packet has a tag indicating that the start packet should be forwarded to any replica that duplicates the data content of the server, the start packet is encapsulated and sent to each replica associated with the server.

10 In a third embodiment, a replica device receives a start packet sent from a client to a server. The start packet is encapsulated. The encapsulated start packet is cracked to determine the client's address. When the replica device is active and not busy, an immediate acknowledgement packet is sent to the client in response to the received start packet. In one implementation, the acknowledgement packet has a source identifier that indicates the replica device. In another implementation, the acknowledgement packet has a source
15 identifier that indicates the server. In yet another aspect, the acknowledgement packet is comprised of a source identifier that indicates the server that is encapsulated with a source identifier that indicates the replica device. Subsequent packets (e.g., after the start and acknowledgement packets) are then sent between the client and sender of the first acknowledgement packet.

20 In another implementation, the invention pertains to a computer system operable to facilitate redirection of traffic between the client and a nearest replica selected from a plurality of replicas. The computer system includes a memory and a processor coupled to the memory. At least one of the memory and the processor are adapted to provide one or more of the above described method operations. In yet another implementation, the

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invention pertains to a computer program product for facilitating redirection of traffic between a server and a client to between the client and a nearest replica selected from a plurality of replicas. The computer program product includes at least one computer readable medium and computer program instructions stored within the at least one computer readable product configured to cause a processing device to provide at least one or more of the above described method operations.

These and other features and advantages of the present invention will be presented in more detail in the following specification of the invention and the accompanying figures which illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a network diagram illustrating a client, server, and two replicas according to a specific embodiment of the present invention;

FIG. 2 is a flowchart illustrating a procedure performed by the client gateway router
5 in accordance with one embodiment of the present invention.

FIG. 3 is a flow chart illustrating a procedure implemented on the server's gateway router, the server's switch, or the web server itself, in accordance with one embodiment of the present invention.

FIG. 4A is a flowchart illustrating a procedure implemented on a replica in
10 accordance with a first embodiment (herein referred to as configuration A) of the present invention.

FIG. 5A is a flowchart illustrating a procedure implemented on the client gateway router in accordance with the first embodiment (configuration A) of the present invention.

FIG. 6A illustrates a procedure implemented on the client gateway router for
15 handling packets to and from the client and nearest replica or server in accordance with the first embodiment (configuration A) of the present invention.

FIG. 4B is a flowchart illustrating a procedure implemented on a replica in accordance with a second embodiment (herein referred to as configuration B) of the present invention.

FIG. 5B is a flowchart illustrating a procedure implemented on the client gateway
20 router in accordance with the second embodiment (configuration B) of the present invention.

FIG. 6B illustrates a procedure implemented on the client gateway router for handling packets to and from the client and nearest replica or server in accordance with the first embodiment (configuration B) of the present invention.

FIG. 4C is a flowchart illustrating a procedure that is implemented on a replica in accordance with a third embodiment (herein referred to as configuration C) of the present invention.

FIG. 5C is a flowchart illustrating a procedure implemented on the client gateway router in accordance with the second embodiment (configuration C) of the present invention.

Figure 6C illustrates a procedure implemented on the client gateway router for handling packets to and from the client and nearest replica or server in accordance with the first embodiment (configuration C) of the present invention.

FIG. 7 is a diagrammatic representation of a router in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Reference will now be made in detail to a specific embodiment of the invention. An example of this embodiment is illustrated in the accompanying drawings. While the invention will be described in conjunction with this specific embodiment, it will be understood that it is not intended to limit the invention to one embodiment. On the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. The present invention may be practiced without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present invention.

FIG. 1 is a simplified network diagram which will be used in conjunction with the flowcharts of FIGS. 2 through 6C to describe specific embodiments of the present invention. As shown, a plurality of client machines 102 which are resident on a local area network (LAN) 104 communicate via a gateway router 106 and wide area network (WAN) 108, e.g., the internet, with main web server 110. Of course, some or all of the clients 102 may communicate with the router 106 through various other configurations, rather than through a LAN. For example, a client may be coupled directly to the router 106 or there may be one or more intermediate routers between a client 102 and the router 106.

The main web server 110 may be associated with a plurality of replica web servers 112. Each replica generally replicates at least a portion of the content on web server 110. Each replica server 112 is preferably located near a significant portion of clients that typically access the main web server 110. In general terms, the present invention enables clients to access a replica web server (or the main web server itself) that is located closest to

such client. For example, if client 102a and replica 112a are both located in Europe, replica 112b is located in Japan, and the main web server in the United States, the client accesses web content from replica 112a.

FIG. 2 is a flowchart illustrating a procedure 200 performed by the client gateway router 106 in accordance with one embodiment of the present invention. Although this procedure 200 is described as occurring on the client's gateway router, of course, it may be implemented on any suitable device associated with the client, such as any intermediate router or the client itself. In the illustrated embodiment, the client gateway router 106 receives a packet from the client 102a in operation 202. It is then determined whether the packet is a start packet in operation 204. This operation may be performed in any suitable manner depending upon the particular protocol used by the packet. For example, it is determined whether the start packet is in the form of a SYN packet when using TCP protocol.

It may then be determined whether the start packet is associated with web content data. In one embodiment, it is determined whether the start packet's destination port is equal to port 80, which is typically used for web traffic. Of course, the present invention may be implemented on other types of data, in addition to web content data. Thus, the technique illustrated in FIG. 2 may determine whether the start packet is associated with other types of data. Alternatively, this determination operation may be eliminated altogether. In the illustrated embodiment, when it is determined that the start packet is associated with web content site in operation 208, a tag is then added to the start packet. The tag may be any suitable format for indicating that the start packet may be redirected to a selected replica associated with the destination server 110. For example, an option byte is added to the start packet's TCP header. The option byte indicates one of two states: redirection is permissible

or redirection is not permissible. A destination identifier entry for the start packet is then added to a Translation Table in operation 212. For example, the start packet's destination IP address (e.g., the address of destination server 110) is added to the Translation Table. The tagged start packet is then forwarded to the server 110 in operation 214.

5 If the packet is not a start packet or the start packet is not destined for a web content site, a tag is not added to the start packet and an entry is not added to the translation table in operations 210 and 212, respectively. Several embodiments for handling a packet that is not a start packet are described further below with reference to Figures 6A through 6C. If the packet is a start packet but is not destined for a web content site, the start packet is merely
10 forwarded to the destination server in operation 214.

FIG. 3 is a flow chart illustrating a procedure 300 implemented on the server's gateway router, the server's switch, or the web server itself, in accordance with one embodiment of the present invention. Initially, the packet that was forwarded from the client gateway router is received in operation 302. It is then determined whether the packet is a
15 start packet in operation 304. If the packet is a start packet, it is then determined whether the start packet has a tag indicating that the start packet may go to a plurality of replicas (e.g., the start packet was tagged by the client gateway router) in operation 308.

If the packet is tagged, it is then determined whether the requested server data is replicatable in operation 310. Any suitable factors may be utilized to divide data into
20 replicatable and non-replicatable data. In one embodiment, static data is replicatable, while dynamic data is not. When a switch that is receiving the start packet is associated with a plurality of servers, the servers may be divided into static content servers and dynamic content servers. In this configuration, each of the static content servers may have associated replicas that duplicate the static server's content. When a start packet is destined for a static
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content server that may have one or more associated replicas, it is then determined that the requested server data is replicatable.

If the requested server content is replicatable, the start packet is encapsulated and forwarded to all replicas associated with the destination server in operation 312. For example, a web server source address and replica destination address are added to the packet header. Within the start packet header, the original client source address and web server source address are now buried behind the web server source address and replica destination address. Additionally, if the packet has not already been received by a web server, the start packet is forwarded to a selected server in operation 314. For example, a switch that is associated with a plurality of web servers may initially receive the start packet and then determine which server will ultimately receive the start packet. The selection may be based on any suitable parameters, such as traffic load and requested data content. The start packet is then forwarded to the selected server in operation 314. Of course, prior to forwarding the start packet to the selected server, the start packet is encapsulated with a switch source address (or gate-way router source address) and a selected server destination address.

If the packet is not a tagged start packet or the requested server content is not replicatable, the start packet is merely forwarded to the selected server (if the start packet has not already been received by the server) in operation 314. For example, the start packet is encapsulated with a switch source address (or gate-way router source address) and a selected server destination address. Of course, if the start packet is already at the destination web server, it is not forwarded. The procedure 300 then ends.

FIG. 4A is a flowchart illustrating a procedure 400 implemented on each replica in accordance with a first embodiment (herein referred to as configuration A) of the present invention. Initially, a start packet is received from either the web server, the server's

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gateway router, or web server's switch in operation 402. If the replica is dead or inactive (i.e., operation 404), nothing happens. If the replica is active but busy in operation 406, the replica then drops the start packet and accordingly does not handle the start packet in operation 408.

5 However, if the replica is not busy or dead, the start packet is then cracked in operation 410. When the start packet is cracked, the original client source address and server destination address are revealed. For example, the server's gate way router source address (or switch or web server) is removed from the header to uncover the underlying client source address and server destination address. The replica may then send an immediate
10 acknowledgment to the client in operation 412. The configuration A replica procedure 400 then ends.

FIG. 5A is a flowchart illustrating a procedure 500 implemented on the client gateway router in accordance with the first embodiment (configuration A) of the present invention. Initially, an acknowledgment is received from a replica or server in operation
15 502. It is then determined whether this is the first acknowledgment received for this connection in operation 504. Since the initial start packet sent by the client to the server may have been forwarded to a plurality of replicas and the server, multiple acknowledgments may be received by the client gateway router. In this embodiment, each replica is configured to send an immediate acknowledgement to the client in response to the forwarded start
20 packet (*e.g.*, FIG. 4A). Since the client will then initially receive an acknowledgement from the replica or server that is located closest to the client, a connection is only established for the first received acknowledgment. Thus, a connection is likely established with the closest device that holds the client's requested data.

When the received acknowledgement is the first acknowledgment received by the client gateway router, a translation table entry is obtained for this connection in operation 506. The translation table contains identification information previously saved by the client gateway router when the start packet was initially sent to the server. This translation table is used to determine whether the destination of the original start packet is now the source of the acknowledgment in operation 508. This is done by matching the identification information in the translation table with corresponding identification information within the acknowledgement packet. For example, the client IP destination address and client destination port number of the acknowledgement packet are matched to a previously stored client source IP address and client source port number of a start packet within the translation table. When a match is found, it is then determined whether the source IP address of the acknowledgment packet is the same as the server destination IP address that was saved with the client source IP address and client port number of the matching entry within the translation table.

If the server is not the source, the entry is updated for this connection in the translation table with the replica's address in operation 510. In other words, the server IP address is associated with the replica IP address for this connection. The translation table may then be utilized by the client gateway router to appropriately translate addresses of packets that are subsequently sent from the client to the replica and from the replica to the client. After the entry is updated, the client gateway router replaces the replica source address with the server source address associated with the current connection and forwards the acknowledgment packet to the client in operation 512.

If the server is the source of the acknowledgement packet, the entry may be deleted for this connection from the translation table in operation 516. That is, an address translation

will not be necessary for packets sent between the client and the original web server (*e.g.*, 110). If this is not the first acknowledgment for this connection, a reset is sent to the source of the acknowledgment in operation 514. That is, connections are terminated for replicas that send acknowledgements that are received after the first acknowledgement for a particular connection. Since the duration of time between the act of sending a start packet and act of receiving an acknowledgement is generally proportional to the distance between the client and the sender of the acknowledgement, connections are likely terminated for replicas that are located at a greater distance from the client than the sender of the first received acknowledgement.

FIG. 6A illustrates a technique 600 implemented on the client gateway router 106 for handling packets to and from the client 102a and the nearest replica 112a in accordance with the first embodiment of the present invention. After a connection is established by sending a first acknowledgment to the client, data may then pass back and forth between the client and the nearest replica. In general terms, the client gateway router allows the client and nearest replica to efficiently exchange data. Preferably, the data exchange is also performed transparently with respect to the client.

Initially, the client gateway router receives a packet in operation 602. It is first determined whether the packet is a start packet or an acknowledgment packet in operation 604. If the packet is a start packet or an acknowledgment packet, procedure 600 ends. Several embodiments of techniques for handling a start packet or an acknowledgment packet are described above with respect to FIGS. 2 and 5A.

If the packet is not a start or acknowledgment packet, the client gateway router searches for the entry in the translation table for this connection in operation 606. For example, the packet's destination IP address and destination port number is compared to

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each entry of client IP address and client port number within the translation table. It is then determined whether a match was found in operation 608. If an entry matches, the matching entry will also contain a corresponding replica address, which will be used in a translation procedure. If there is no match, the packet is simply forwarded to its destination in operation 616. For example, there may not be a match when the first received acknowledgement originated from the original destination server 110, instead of a replica.

When a match is found, it is then determined whether the packet is from the client side in operation 610. In other words, it is determined whether the packet is being sent from the client to a destination server. If the packet is from the client side, the client gateway router replaces the server destination address with the replica destination address of the matching entry that was obtained from the translation table and the “translated” packet is forwarded to the replica. If the packet is not from the client side, the client gateway router replaces the replica source address with the server source address of the matching entry from the translation table and forwards the packet to the client in operation 612. In other words, the client gateway router may be configured to perform a Network Address Translation (NAT) procedure on packets subsequently received after the acknowledgement packet. The packet handling procedure 600 then ends.

Configuration A (*e.g.*, the client gateway router performs a NAT) has several associated advantages. For example, the client gateway router and client are aware of who sent the packet and are able to match the sending replica to the original destination server. In effect, the client server is able to verify the authentication of the replica by matching the source IP address and source port number of the start packet with the destination IP address and destination port number of the acknowledgement packet and subsequent packets sent by a nearest replica. The values of these two addresses are typically unique.

Although configuration A provides a relatively secure mechanisms for traffic transmission, it does require a significant amount of overhead, especially when translating data sent from a replica to the client since this data tends to be quite large (e.g., web content). Accordingly, the present invention may be implemented in any number of configurations to achieve efficient traffic handling between a client and a nearest replica (or the destination server if it is closer to the client than the other replicas), while minimizing or eliminating the overhead penalty of the configuration A implementation. In sum, the above described configuration A replica and client gateway techniques are not meant to limit the scope of the invention.

FIG. 4B is a flowchart illustrating a procedure 430 implemented on a replica in accordance with a second embodiment (herein referred to as configuration B) of the present invention. Operations 402 through 410 are common to both configuration A and configuration B replicas. However, after the start packet is cracked in operation 410, a different operation is performed in configuration B. Rather than send an immediate acknowledgment packet having a client destination address and replica source address to the client as done by the configuration A replica of Figure 4A, the configuration B replica spoofs the server when sending an immediate acknowledgment to the client (see operation 442). That is, the configuration B replica encapsulates its acknowledgement response, which includes a replica source address and a client destination address, with the server source IP address and the client destination IP address.

FIG. 5B is a flowchart illustrating a procedure implemented on the client gateway router with the second embodiment (i.e., configuration B) of the present invention. Initially, the client gateway router receives an acknowledgement packet that originates supposedly from the original destination server (e.g., 110 of FIG. 1) in operation 532. That is, the

search within the translation table for entries corresponding to packets that do not originate from the client side. However, acknowledgement packets that do not originate from the client side are an exception to this rule as shown in FIG. 5B (*i.e.*, the translation table is searched and an entry may be updated). When the packet is from the client side and a match is found in the translation table, the configuration B gateway router simply replaces the server destination address with the corresponding replica destination address and forwards the modified packet to the replica in operation 636. The procedure 630 then ends for this received packet.

Although the configuration B implementation is more efficient than the configuration A implementation since only packets sent from the client side are translated, this technique may not be acceptable under certain conditions. For example, since a replica spoofs the server, the gateway router may inadvertently initiate reset procedures for packets sent from the replica to the client. The client gateway router may send a reset when the packet is coming into a different port number than the original start packet for this connection. In this situation, the client gateway router may be configured to send a reset to inhibit hackers from breaking into a connection by masquerading as the intended destination server.

FIG. 4C is a flowchart illustrating a procedure 450 that is implemented on a replica in accordance with a third embodiment (herein referred to as configuration C) of the present invention. Operation 402 through 410 are common to Figures 4C, 4B, and 4A and are described above. However, after the start packet is cracked in operation 410, an acknowledgment is encapsulated with the replica source address and client destination address and sent to the client in operation 462. That is, the server source address and client destination address are encapsulated. The replica configuration C procedure 450 then ends.

Figure 5C is a flowchart illustrating a procedure 550 implemented on the client gateway router. In general terms, the client gateway router performs tunneling on packets sent from a replica to the client. Initially, the client gateway router receives an acknowledgement packet from the original destination server (*e.g.*, 110 of FIG. 1) or a replica in operation 552. The received acknowledgement is then cracked in operation 554 if the acknowledgement has been encapsulated (*e.g.*, by a replica).

Operations 504 through 516 are common to both configuration A and configuration C replicas. That is, it is determined whether the acknowledgement is the first received acknowledgement and whether the source of the acknowledgement is not the original destination server. If these conditions are met, the translation table is updated by associating the replica's address with original destination server and the cracked acknowledgment is then forwarded to the client in operation 564. The configuration C procedure 550 then ends.

Figure 6C is a flowchart illustrating a procedure 650 implemented on the client gateway router for handling packets after a connection has been established between a client and a replica or a server in accordance with one embodiment of the present invention. Initially, a packet is received in operation 652. The packet may be sent from the client to the server or from a replica or the server to the client. Operations 606 through 610, and 616 are common to both configuration A and configuration C replicas. That is, when a packet is not a start or acknowledgement packet, the client gateway router searches for an entry within the translation table that corresponds to the packet. If there is a match found, it is then determined whether the packet is from the client side in operation 610. If the packet is from the client side, the packet is encapsulated with the replica IP destination address and client's source IP address and the encapsulated packet is then forwarded to the replica in operation 656. If the packet is not from the client side, the packet is merely cracked and forwarded to

the client in operation 658. The configuration C procedure 650 then ends for this received packet.

Since packets going from the client to the replica (or server) are only modified and packets going to the client are merely cracked, the configuration C technique provides an efficient mechanisms for shuttling traffic back and forth between a client and a closest replica. Since packets going to the client from the replica tend to be much larger than the traffic going from the client to the replica, encapsulation will likely be performed on the smaller packets and not the larger packets. Since encapsulation requires more resources than simply cracking a packet, the configuration C technique will likely result in the utilization of less resource than, for example, the configuration A technique that modifies packets going both to and from the client. Additionally, since packets from the replica are cracked by the client gateway router, the gateway router can verify the authenticity of each packet (*e.g.*, by comparing the destination port number of the cracked packet to the source port number of the corresponding start packet).

Generally, portions of the traffic redirection techniques of the present invention may be implemented on software and/or hardware. For example, they can be implemented in an operating system kernel, in a separate user process, in a library package bound into network applications, on a specially constructed machine, or on a network interface card. In a specific embodiment of this invention, a technique of the present invention is implemented in software such as an operating system or in an application running on an operating system.

A software or software/hardware hybrid traffic redirection system of this invention is preferably implemented on a general-purpose programmable machine selectively activated or reconfigured by a computer program stored in memory. The programmable machine may be in the form of a general purpose computer that is configured to implement a cache

system. The computer system generally includes a memory, processor, and network interface modules.

Such programmable machine may also be a network device designed to handle network traffic. Such network devices typically have multiple network interfaces including frame relay and ISDN interfaces, for example. Specific examples of such network devices include routers and switches. For example, the traffic redirection systems of this invention may be specially configured routers such as specially configured router models 1600, 2500, 2600, 3600, 4500, 4700, 7200, 7500, and 12000 available from Cisco Systems, Inc. of San Jose, California. A general architecture for some of these machines will appear from the description given below. In an alternative embodiment, a traffic redirection system may be implemented on one or more general-purpose network host machine such as a personal computer or workstation. Further, techniques of the invention may be at least partially implemented on a card (e.g., an interface card) for a network device or a general-purpose computing device.

Referring now to FIG. 7, a router 10 suitable for implementing portions of the present invention includes a master central processing unit (CPU) 62, interfaces 68, and a bus 15 (e.g., a PCI bus). When acting under the control of appropriate software or firmware, the CPU 62 is responsible for such router tasks as routing table computations and network management. It may also be responsible for determining the tasks described above for the client gateway router, the web server, the switch, the server gateway router, or each replica. It preferably accomplishes all these functions under the control of software including an operating system (e.g., the Internetwork Operating System (IOS®) of Cisco Systems, Inc.) and any appropriate applications software. CPU 62 may include one or more processors 63 such as a processor from the Motorola family of microprocessors or the MIPS family of

microprocessors. In an alternative embodiment, processor 63 is specially designed hardware for controlling the operations of router 10. In a specific embodiment, a memory 61 (such as non-volatile RAM and/or ROM) also forms part of CPU 62. However, there are many different ways in which memory could be coupled to the system. Memory block 61 may be used for a variety of purposes such as, for example, caching and/or storing data, programming instructions, etc.

The interfaces 68 are typically provided as interface cards (sometimes referred to as "line cards"). Generally, they control the sending and receiving of data packets over the network and sometimes support other peripherals used with the router 10. Among the interfaces that may be provided are Ethernet interfaces, frame relay interfaces, cable interfaces, DSL interfaces, token ring interfaces, and the like. In addition, various very high-speed interfaces may be provided such as fast Ethernet interfaces, Gigabit Ethernet interfaces, ATM interfaces, HSSI interfaces, POS interfaces, FDDI interfaces and the like. Generally, these interfaces may include ports appropriate for communication with the appropriate media. In some cases, they may also include an independent processor and, in some instances, volatile RAM. The independent processors may control such communications intensive tasks as packet switching, media control and management. By providing separate processors for the communications intensive tasks, these interfaces allow the master microprocessor 62 to efficiently perform routing computations, network diagnostics, security functions, etc.

Although the system shown in FIG. 7 is one specific router of the present invention, it is by no means the only router architecture on which the present invention can be implemented. For example, an architecture having a single processor that handles

communications as well as routing computations, etc. is often used. Further, other types of interfaces and media could also be used with the router.

Regardless of network device's configuration, it may employ one or more memories or memory modules (such as, for example, memory block 65) configured to store data, program instructions for the general-purpose network operations and/or bucket allocation and assignment mechanisms described herein. The program instructions may control the operation of an operating system and/or one or more applications, for example. The memory or memories may also be configured to store the above described Translation Table.

Because such information and program instructions may be employed to implement the systems/methods described herein, the present invention relates to machine readable media that include program instructions, state information, etc. for performing various operations described herein. Examples of machine-readable media include, but are not limited to, magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROM disks; magneto-optical media such as floptical disks; and hardware devices that are specially configured to store and perform program instructions, such as read-only memory devices (ROM) and random access memory (RAM). The invention may also be embodied in a carrier wave travelling over an appropriate medium such as airwaves, optical lines, electric lines, etc. Examples of program instructions include both machine code, such as produced by a compiler, and files containing higher level code that may be executed by the computer using an interpreter.

Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. Therefore, the described embodiments should be taken as illustrative and not restrictive, and the invention should not be limited to

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the details given herein but should be defined by the following claims and their full scope of equivalents.

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